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# SCIENCE

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## SOME PROBLEMS IN EVOLUTION<sup>1</sup>

It was nearly 100 years ago that Charles Darwin began his scientific studies in the University of Edinburgh. In this illustrious center of intellectual activity he met various friends keenly interested in natural history, and attended the meetings of scientific societies, and it was doubtless here that were sown many of the seeds destined to bear such glorious fruit many years later. No more fitting subject, I think, could be found for an address than certain problems relating to his doctrine of evolution. That controversy perpetually rages round it is a healthy sign. For we must take care in science lest doctrine should pass into dogma, unquestioned and accepted merely on authority. So from time to time it is useful to reexamine in the light of new knowledge the very foundations on which our theories are laid.

Perhaps the best way of treating these general subjects is by trying to answer some definite questions. For instance, we may ask: "Why are some characters inherited and others not?" By characters we mean all those qualities and properties possessed by the organism, and by the enumeration of which we describe it; its weight, size, shape, color, its structure, composition and activities. Next, what do we mean by "inherited"? It is most important, if possible, clearly to define this term, since much of the controversy in writings on evolution is due to its use by various authors with a very different significance—sometimes as mere reappearance, at other times as actual transmission or transference from one generation to the next. Now, I propose to use the word inheritance merely to signify the reappearance in the offspring of a character possessed by the ancestor—a fact

<sup>1</sup> Address of the president of Section D—Zoology—British Association for the Advancement of Science, Edinburgh, September, 1921.

which may be observed and described, regardless of any theory as to its cause. Our question, then, is: "Why do some characters reappear in the offspring and others not?"

It is sometimes asserted that old-established characters are inherited, and that newly begotten ones are not, or are less constant, in their reappearance. This statement will not bear critical examination. For, on the one hand, it has been conclusively shown by experimental breeding that the newest characters may be inherited as constantly as the most ancient, provided they are possessed by both parents.<sup>2</sup> While, on the other hand, few characters in plants can be older than the green color due to chlorophyll, yet it is sufficient to cut off the light from a germinating seed for the greenness to fail to appear. Again, ever since Devonian times vertebrates have inherited paired eyes; yet, as Professor Stockard has shown, if a little magnesium chloride is added to the sea-water in which the eggs of the fish *Fundulus* are developing, they will give rise to embryos with one median cyclopean eye! Nor is the suggestion any happier that the, so to speak, more deep-seated and fundamental characters are more constantly inherited than the trivial or superficial. A glance at organisms around us, or the slightest experimental trial, soon convinces us that the apparently least-important character may reappear as constantly as the most fundamental. But while an organism may live without some trivial character, it can rarely do so when a fundamental character is absent, hence such incomplete individuals are seldom met in Nature.

Yet undoubtedly some characters reappear without fail and others do not. If it is neither age nor importance, what is it that determines their inheritance? The answer is that for a character to reappear in the offspring it is essential that the germinal factors and the environmental conditions which cooperated in its formation in the ancestor should both be present. Inheritance depends on this con-

<sup>2</sup> We purposely set aside complications due to hybridization and Mendelian segregation, which do not directly bear on the questions at issue.

dition being fulfilled. For all characters are of the nature of responses to environment,<sup>3</sup> they are the products or results of the interaction between the factors of inheritance (germinal factors) and the surrounding conditions or stimuli. This power of response or reaction is no mysterious property of organisms—it is the effect produced, the disturbance brought about by the application of a stimulus. All the special properties and activities of living organisms ultimately depend on their metabolism, of which growth and reproduction are the chief manifestations. The course of metabolism, and, consequently, the development in the individual of a character, is molded or conditioned by the environmental stimuli under which it takes place. On the other hand, the living substance, protoplasm, which is undergoing metabolism, is the material basis of the organism. It has a specific composition and structure peculiar to the particular kind of organism concerned, and this is handed on to the offspring in the germ-cells from which starts the new generation. The inheritance of a character is due, then, not only to the actual transmission or transference of this specific "germ-plasm" containing the same factors of inheritance (germinal factors) as those from which the parent developed, but also to this factorial complex developing under the same conditions (environmental stimuli), as those under which the parent developed. Any alteration either in the effective environmental stimuli or in the germinal factors will produce a new result, will give rise to a new character, will cause the old character to appear no longer.

Now what is actually transmitted from one generation to the next is the complex of germinal factors. Hence we should carefully distinguish between transmission and inheritance.

<sup>3</sup> In a letter to *Nature* Sir Ray Lankester long ago drew attention to the importance of this consideration when discussing inheritance. He also pointed out that Lamarck's first law, that a new stimulus alters the characters of an organism, contradicts his second law, that the effects of previous stimuli are fixed by inheritance. (*Nature*, Vol. LI., 1894.)

Much of the endless confusion and interminable controversies about the inheritance of so-called "acquired characters" is due to the neglect of this important distinction. For it is quite clear that whereas factors may be transmitted, characters as such never are. The characters of the adult, being responses, are not present as such in the fertilized ovum from which it develops, they are produced anew at every generation.<sup>4</sup> No distinction in kind or value can be drawn between characters.

If some are inherited regularly and others are not, the distinction lies not in the nature or mode of production of the characters themselves, but in the constancy of the factors and conditions which give rise to them. Thus, although there is only one kind of character, there are two kinds of variation.

Much of the confusion in evolutionary literature is, I think, due to the use of the word variation in a loose manner. Sometimes it is taken to mean the degree of divergence between two individuals; sometimes the character itself in which they differ, such as a color or spot on a butterfly's wing, at other times a variety or race differing from the normal form of the species. If clearness of thought and expression is to be attained, the word variation should mean the extent or degree of difference between two individuals or between an individual and the average of the species, the divergence of the new form from the old; not a new character or assemblage of characters, but a difference which can be measured or at least estimated. We shall then find that a variation is of one of two kinds (which may, of course, be combined): the first kind is due to some change in the complex of germinal factors.

The second kind, to which the name mutation has been applied, will, under constant con-

<sup>4</sup> In other words, all characters are "acquired during the lifetime of the individual," and "inherited" in the sense here defined has just the same meaning. Much the same view was advocated by Professor A. Sedgwick in his address to this Section at Dover in 1899, and it has also been developed by Dr. Archdall Reid and others.

ditions, be inherited since the new complex of factors will be transmitted to subsequent generations. The first kind of variation, which has been called a modification, will also be inherited, provided, of course, the change of stimulus persists. In either case, new characters will result. But here, again, we must be careful not to apply the terms mutation and modification to the characters themselves, as is so often done;<sup>5</sup> for we then reintroduce the confusion already exposed in the popular but misleading distinction between "acquired" and "non-acquired" characters. The characters due to mutation or modification are, of course, indistinguishable by mere inspection, and can only be separated by experiment. A mutation once established should give rise, under uniform conditions, to a new heritable character, and may be detected by crossing with normal members of the species.

So far observations and tests have shown that new characters due to modification only reappear so long as the new stimulus persists. The difference lies not in the value or permanence of the new character, but in the causes which give rise to it.<sup>6</sup>

It is little more than a platitude to state that, for the production of an organism or of any of its characters, both germinal factors and environmental stimuli are necessary, and that if evolution is to take place there must be change in one or both. Yet the changes in the factors may be held to be the more important.

<sup>5</sup> The name "mutation" might be given to the alteration in the factors instead of the variation due to it. The latter might then be termed a mutational variation and would be opposed to a modificational variation. At present the term "mutation" is applied to three different things: the factorial change, the variation or difference, and the new product response or character.

<sup>6</sup> We might perhaps distinguish the two cases by calling them constant and inconstant characters, or "natural" and "acquired," as is commonly done when describing immunity. It should be meant thereby that one is acquired usually (under normal conditions), the other occasionally (when infection occurs). Error creeps in when the term "acquired" is opposed to "non-acquired" or to "inherited."

In an environment which on the whole alters but little, evolution progresses by the cumulation along diverging lines of adaptation of new characters due to mutation. Thus natural selection indirectly preserves those factorial complexes which respond in a favorable manner. In other words, an organism, to survive in the struggle for existence, must present that assemblage of factors of inheritance which, under the existing environmental conditions, will give rise to advantageous characters.

In answer to a further question, let us now try to explain what we mean when we contrast the organism with its environment. In its simplest and most abstract form a living organism may be likened to a vortex. That mixture of highly complex proteins we call protoplasm, the physical basis of life, is perpetually undergoing transformations of matter and energy, so long as life persists. Towards the center of the vortex the highest compounds are continually being built up and continually being broken down; new material (food, water, oxygen) and energy are brought in at the periphery, and old material and energy (work and heat) thrown out. The principle of the conservation of energy and matter holds good in organized living processes as it does in the inorganic world outside. This is the process we call metabolism, and it is at the base of all the manifestations of life. From the point of view of biological science life is founded on a complex and continuous physico-chemical process of endless duration so long as conditions are favorable; just as a fire will continue to burn so long as fuel is at hand. No one step, no single substance, can be said to be living; the whole chain of substances and reactions, every link of which is essential, constitutes the life-process. A stream of non-living matter with stored-up energy is built up into the living vortex, and again passes out as dead matter, having yielded up the energy necessary for the performance of the various activities of the organism. If more is taken in than is given out it will grow and sub-divide. The complexity of the organism may increase by the

formation of subsidiary, more or less interdependent, vortices within it. The perpetual growth and transmission of factors of inheritance, the continuity of the germ-plasm, is but another aspect of the continuity of the metabolic process forming the basis of the continuity of life in evolution.

But all the environmental stimuli are not external to the organism. Just as the various steps in the metabolic process are dependent on those which preceded them, so when an organism becomes differentiated into parts, when the main process becomes subdivided into subsidiary ones, these react on each other. What is internal to the whole becomes external to the part. An external stimulus may set up an internal metabolic change, giving rise to a response whose extent and nature depend on the structure of the mechanism and its state when stimulated, that is to say, on the effect of previous responses. Such a response may act as an internal stimulus giving rise to a further response, which may modify the first, and so on. Parts thus become marvelously fitted to set going, inhibit, or regulate each other's action; and thus arises that power of individual adaptation, or self-regulation, so characteristic of living organisms. The processes of temperature regulation, of respiration, of excretion are examples of such delicate self-regulating mechanisms in ourselves. But one of the great advantages thereby gained by organisms is that they can regulate their own growth and ensure their own "right" development. Whereas the simplest plants and animals are to a great extent, so to speak, at the mercy of their external environment, except in so far as they can move from unfavorable to more favorable surroundings; whereas their characters appear in response to external stimuli which may or may not be present, and over which they have little or no control—the higher organisms (more especially the higher animals), as it were, gradually substitute internal for external stimuli. Food material is provided in the ovum, and the size, structure and time of appearance of various characters are regulated to a great extent by use and by the secretions of various

endocrinal glands, the action of which has been so successfully studied, among others, by Sir Sharpey Schaffer in this University. Thus, as is well shown in man, the higher animals acquire considerable independence, and are little affected in their development by minor changes of environment. Inheritance is thus made secure by ensuring that the necessary conditions are always present.

We may seem to have wandered far from our original question; but the answer now appears to be that only those characters can be regularly inherited which depend for their appearance on conditions always fulfilled in the normal environment (external or internal); and those characters will not be regularly inherited which depend on stimuli that may or may not be present. Thus, while the offspring of a dark-skinned race will be dark in whatever climate they are born, those of a fair-skinned race will be born fair, but may be darkened by sun-burn, if they spend their holiday in the open.

Now it will be said, and not without some truth, that all this is mere commonplace admitted by all; but, if so, it is, I think, often ignored or misunderstood in discussions on heredity, more especially in semi-popular writings, and sometimes even in scientific works. However, I quite willingly admit that the real problems Darwin left to be solved by the evolutionist are the nature of the germinal factors themselves, and more especially the origin of the differences between them, the origin of those changes which give rise to mutations.

That these factors<sup>7</sup> must at least be self-

<sup>7</sup> Herbert Spencer's "physiological units," Darwin's "pangens," Weismann's "determinants," are all terms denoting factors, but with somewhat different meanings. More recently Professor W. Johannsen ("Elemente der exakten Erbliehkeitslehre," 1909) has proposed the term "gene" for a factor, "genotype" for the whole assemblage of factors transmitted by a species, and "phenotype" for the characters developed from them. This clear system of nomenclature, although much used in America, has not been generally adopted in this country.

propagating substances, subsidiary vortices in the main stream of metabolizing living protoplasm, is certain, since they grow and multiply repeatedly, to be distributed to new generations of germ-cells. That they may be relatively constant and remain unaltered for generations seems also certain, since organisms or their parts can continue almost unchanged for untold ages. That they can act independently, can be separately distributed into different germ-cells, and can be re-combined seems likewise to have been proved by the brilliant work of Mendel and his followers. So independent and constant do they appear to be that modern students of heredity tend to treat them as so many beads in a row, as separate particles themselves endowed with all the properties of independent living organisms, the very properties we wish to explain. While not prepared to accept these views without qualification, it seems to me that it can scarcely be doubted that some such units must exist whether in the form of discrete particles or merely of separable substances. But not until these factors have been brought into relation with the general metabolism of the organism, as links in the chain of processes, will the problem of inheritance approach solution. If the theory is to be completed it must attempt to explain how they come to differ, how their orderly behavior is regulated, in what functional relation they stand to each other, what is the metabolic bond between them. That harmonious processes may be carried out by discrete elements in cooperation is shown in cases of symbiotic combinations such as the lichens, or the green algæ in such animals as *Hydra* and *Convoluta*. Here an originally independent organism takes its place and does its work regularly in another organism, and may even be propagated and transmitted from one generation to the next in the germ-cell! Most instructive, also, are the recently studied cases of bacteria and yeasts living regularly in certain special tissues of various species of insects, where they exert a definite influence on the metabolism (see the works of Pierantoni, Buchner, Gla-

ser). These no doubt are mere analogies, but they serve.

In all probability, then, factors of inheritance exist, and the fundamental problem of Biology is, how are the factors of an organism changed, or how does it acquire new factors? In spite of its vast importance, it must be confessed that little advance has been made towards the solution of this problem since the time of Darwin, who considered that variation must ultimately be due to the action of the environment. This conclusion is inevitable, since any closed system will reach a state of equilibrium and continue unchanged, unless affected from without. To say that mutations are due to the mixture or reshuffling of pre-existing factors is merely to push the problem a step farther back, for we must still account for their origin and diversity. The same objection applies to the suggestion that the complex of factors alters by the loss of certain of them. To account for the progressive change in the course of evolution of the factors of inheritance and for the building up of the complex it must be supposed that from time to time new factors have been added; it must further be supposed that new substances have entered into the cycle of metabolism, and have been permanently incorporated as self-propagating ingredients entering into lasting relation with preexisting factors. We are well aware that living protoplasm contains molecules of large size and extraordinary complexity, and that it may be urged that by their combination in different ways, or by the mere regrouping of the atoms within them, an almost infinite number of changes may result, more than sufficient to account for the mutations which appear. But this does not account for the building up of the original complex. If it must be admitted that such a building process once occurred, what right have we to suppose that it ceased at a certain period? We are driven, then, to the conclusion that in the course of evolution new material has been swept from the banks into the stream of germ-plasm.

If one may be allowed to speculate still further, may it not be supposed that factors

differ in their stability?—that whereas the more stable are merely bent, so to speak, in this or that direction by the environment, and are capable of returning to their original condition, as a gyroscope may return to its former position when pressure is removed, other less stable factors may be permanently distorted, may have their metabolism permanently altered, may take up new substance from the vortex, without at the same time upsetting the system of delicate adjustments whereby the organism keeps alive? In some such way we imagine factorial changes to be brought about and mutations to result.

Let it not be thought for a moment that this admission that factors are alterable opens the door to a Lamarckian interpretation of evolution! According to the Lamarckian doctrine, at all events in its modern form, a character would be inherited after the removal of the stimulus which called it forth in the parent. Now of course, a response once made, a character once formed, may persist for longer or shorter time according as it is stable or not; but that it should continue to be produced when the conditions necessary for its production are no longer present is unthinkable. It may, however, be said that this is to misrepresent the doctrine, and that what is really meant is that the response may so react on and alter the factor as to render it capable of producing the new character under the old conditions. But is this interpretation any more credible than the first?

Let us return to the possible alteration of factors by the environment. Unfortunately there is little evidence as yet on this point. In the course of breeding experiments the occurrence of mutations has repeatedly been observed, but what led to their appearance seems never to have been so clearly established as to satisfy exacting critics. Quite lately, however, Professor M. F. Guyer, of Wisconsin, has brought forward a most interesting case of the apparent alteration at will of a factor or set of factors under definite well-controlled conditions.<sup>8</sup> You will re-

<sup>8</sup> *American Naturalist*, Vol. LV., 1921; *Jour. of Exper. Zoology*, Vol. XXXI., 1920.

member that if a tissue substance, blood-serum, for instance, of one animal be injected into the circulation of another, this second individual will tend to react by producing an anti-body in its blood to antagonize or neutralize the effect of the foreign serum. Now Professor Guyer's ingenious experiments and results may be briefly summarized as follows. By repeatedly injecting a fowl with the substance of the lens of the eye of a rabbit he obtained anti-lens serum. On injecting this "sensitized" serum into a pregnant female rabbit it was found that, while the mother's eyes remained apparently unaffected, some of her offspring developed defective lenses. The defects varied from a slight abnormality to almost complete disappearance. No defects appeared in untreated controls, no defects appeared with non-sensitized sera. On breeding the defective offspring for many generations these defects were found to be inherited, even to tend to increase and to appear more often. When a defective rabbit is crossed with a normal one the defect seems to behave as a Mendelian recessive character, the first generation having normal eyes and the defect reappearing in the second. Further, Professor Guyer claims to have shown that the defect may be inherited through the male as well as the female parent, and is not due to the direct transmission of anti-lens from mother to embryo *in utero*.

If these remarkable results are verified, it is clear that an environmental stimulus, the anti-lens substance, will have been proved to affect not only the development of the lens in the embryo, but also the corresponding factors in the germ-cells of that embryo; and that it causes, by originating some destructive process, a lasting transmissible effect giving rise to a heritable mutation.

Professor Guyer, however, goes farther, and argues that, since a rabbit can also produce anti-lens when injected with lens substance, and since individual animals can even produce anti-bodies when treated with their own tissues, therefore the products of the tissues of an individual may permanently affect the

factors carried by its own germ-cells. Moreover he asks, pointing to the well-known stimulative action of internal secretions (hormones and the like), if destructive bodies can be produced, why not constructive bodies also? And so he would have us adopt a sort of modern version of Darwin's theory of pangenesis, and a Lamarckian view of evolutionary change.

But surely there is a wide difference between such a poisonous or destructive action as he describes and any constructive process. The latter must entail, as I tried to show above, the drawing of new substances into the metabolic vortex. Internal secretions are themselves but characters, products (perhaps of the nature of ferments) behaving as environmental conditions, not as self-propagating factors, molding the responses, but not permanently altering the fundamental structure and composition of the factors of inheritance.

Moreover, the early fossil vertebrates had, in fact, lenses neither larger nor smaller on the average than those of the present day. If destructive anti-lens had been continually produced and had acted, its effect would have been cumulative. A constructive substance must, then, have also been continually produced to counteract it. Such a theory might perhaps be defended; but would it bring us any nearer to the solution of the problem?

The real weakness of the theory is that it does not escape from the fundamental objections we have already put forward as fatal to Lamarckism. If an effect has been produced, either the supposed constructive substance was present from the first, as an ordinary internal environmental condition necessary for the normal development of the character, or it must have been introduced from without by the application of a new stimulus. The same objection does not apply to the destructive effect. No one doubts that if a factor could be destroyed by a hot needle or picked out with fine forceps the effects of the operation would persist throughout subsequent generations.

Nevertheless, these results are of the greatest interest and importance, and, if corrob-



orated, will mark an epoch in the study of heredity, being apparently the first successful attempt to deal experimentally with a particular factor or set of factors in the germ-plasm.

There remains another question we must try to answer before we close, namely, "What share has the mind taken in evolution?" From the point of view of the biologist, describing and generalizing on what he can observe, evolution may be represented as a series of metabolic changes in living matter molded by the environment. It will naturally be objected that such a description of life and its manifestations as a physico-chemical mechanism takes no account of mind. Surely, it will be said, mind must have affected the course of evolution, and may indeed be considered as the most important factor in the process. Now, without in the least wishing to deny the importance of the mind, I would maintain that there is no justification for the belief that it has acted or could act as something guiding or interfering with the course of metabolism. This is not the place to enter into a philosophical discussion on the ultimate nature of our experience and its contents, nor would I be competent to do so; nevertheless, a scientific explanation of evolution can not ignore the problem of mind if it is to satisfy the average man.

Let me put the matter as briefly as possible at the risk of seeming somewhat dogmatic. It will be admitted that all the manifestations of living organisms depend, as mentioned above, on series of physico-chemical changes continuing without break, each step determining that which follows; also that the so-called general laws of physics and of chemistry hold good in living processes. Since, so far as living processes are known and understood, they can be fully explained in accordance with these laws, there is no need and no justification for calling in the help of any special vital force or other directive influence to account for them. Such crude vitalistic theories are now discredited, but tend to return in a more subtle form as the doctrine

of the interaction of body and mind, of the influence of the mind on the activities of the body. But, try as we may, we can not conceive how a physical process can be interrupted or supplemented by non-physical agencies. Rather do we believe that to the continuous physico-chemical series of events there corresponds a continuous series of mental events inevitably connected with it; that the two series are but partial views or abstractions, two aspects of some more complete whole, the one seen from without, the other from within, the one observed, the other felt. One is capable of being described in scientific language as a consistent series of events in an outside world, the other is ascertained by introspection, and is describable as a series of mental events in psychical terms. There is no possibility of the one affecting or controlling the other, since they are not independent of each other. Indissolubly connected, any change in the one is necessarily accompanied by a corresponding change in the other. The mind is not a product of metabolism as materialism would imply, still less an epiphenomenon or meaningless by-product as some have held. I am well aware that the view just put forward is rejected by many philosophers, nevertheless it seems to me to be the best and indeed the only working hypothesis the biologist can use in the present state of knowledge. The student of biology, however, is not concerned with the building up of systems of philosophy, though he should realize that the mental series of events lies outside the sphere of natural science.

The question, then, which is the more important in evolution, the mental or the physical series, has no meaning, since one can not happen without the other. The two have evolved together *pari passu*. We know of no mind apart from body, and have no right to assume that metabolic processes can occur without corresponding mental processes, however simple they may be.

Simple response to stimulus is the basis of all behavior. Responses may be linked together in chains, each acting as a stimulus to

start the next; they can be modified by other simultaneous responses, or by the effects left behind by previous responses, and so may be built up into the most complicated behavior. But, owing to our very incomplete knowledge of the physical-chemical events concerned, we constantly, when describing the behavior of living organisms, pass, so to speak, from the physical to the mental series, filling up the gaps in our knowledge of the one from the other. We thus complete our description of behavior in terms of mental processes we know only in ourselves (such as feeling, emotion, will) but infer from external evidence to take place in other animals.

In describing a simple reflex action, for instance, the physico-chemical chain of events may appear to be so completely known that the corresponding mental events are usually not mentioned at all, their existence may even be denied. On the contrary, when describing complex behavior when impulses from external or internal stimuli modify each other before the final result is translated into action, it is the intervening physico-chemical processes which are unknown and perhaps ignored, and the action is said to be voluntary or prompted by emotion or the will.

The point I wish to make, however, is that the actions and behavior of organisms are responses, are characters in the sense described in the earlier part of this address. They are inherited, they vary, they are selected, and evolve like other characters. The distinction so often drawn by psychologists between instinctive behavior said to be inherited and intelligent behavior said to be acquired is as misleading and as little justified in this case as in that of structural characters. Time will not allow me to develop this point of view, but I will only mention that instinctive behavior is carried out by a mechanism developed under the influence of stimuli, chiefly internal, which are constantly present in the normal environmental conditions, while intelligent behavior depends on responses called forth by stimuli which may or may not be present. Hence, the former is, but the latter may or

may not be inherited. As in other cases, the distinction lies in the factors and conditions which produce the results. Instinctive and intelligent behavior are usually, perhaps always, combined, and one is not more primitive or lower than the other.

It would be a mistake to think that these problems concerning factors and environment, heredity and evolution, are merely matters of academic interest. Knowledge is power, and in the long run it is always the most abstruse researches that yield the most practical results. Already, in the effort to keep up and increase our supply of food, in the constant fight against disease, in education, and in the progress of civilization generally, we are beginning to appreciate the value of knowledge pursued for its own sake. Could we acquire the power to control and alter at will the factors of inheritance in domesticated animals and plants, and even in man himself, such vast results might be achieved that the past triumphs of the science would fade into insignificance.

Zoology is not merely a descriptive and observational science, it is also an experimental science. For its proper study and the practical training of students and teachers alike, well-equipped modern laboratories are necessary. Moreover, if there is to be a useful and progressive school contributing to the advance of the science, ample means must be given for research in all its branches. Life doubtless arose in the sea, and in the attempt to solve most of the great problems of biology the greatest advances have generally been made by the study of the lower marine organisms. It would be a thousand pities, therefore, if Edinburgh did not avail itself of its fortunate position to offer to the student opportunities for the practical study of marine zoology.

In his autobiography, Darwin complains of the lack of facilities for practical work—the same need is felt at the present time. He would doubtless have been gratified to see the provision made since his day and the excellent use to which it has been put; but what seems adequate to one generation becomes insuffi-

cient for the next. We earnestly hope that any appeal that may be made for funds to improve this Department of Zoology may meet with the generous response it certainly deserves.

EDWIN S. GOODRICH

### THE SPIRIT OF RESEARCH

THE recent World War emphasized the importance of scientific investigation and as a result there has followed a vigorous campaign to promote research in America. In consequence a great deal has been published recently concerning the *mechanism* of research; how we may cooperate; how the large university with superior equipment may help the teacher in the small institution to keep alive the hope that is within him to do research work; we have bulletins issued from time to time which bring certain fields of knowledge up-to-date; we have compendia on the technique of research; in a host of different ways the machinery for doing research is being cleaned and oiled and must run infinitely better than it has in the past. This is all exceedingly important and must be done if we are to take a share in the program of scientific investigation. Back of all this machinery, however, must be human minds and the progress we make in the search for truth is going to depend on the *spirit* which animates these human minds guiding this machinery of research and taking part in the actual investigation of the many unsolved problems about us and trying to

Read the world's old riddles well.

In other words, the motives which prompt men to spend long hours and sleepless nights trying to fathom the depths of the unknown will determine the success individuals have in their work.

As one goes over the records of human achievements in history, there is developed in the reader a sense that the great achievements of the world have been in the realm of the spiritual. (Using that term in its broadest meaning.) The Magna Charta, the advent of the Pilgrim Fathers, the Boston

Tea Party, the Declaration of Independence, the Emancipation Proclamation are events and articles having the greatest spiritual significance. Great because they were staged for the uplift of the masses and not for the aggrandizement of the few as the failures of Alexander, Napoleon and William the Second are glaring examples.

It would seem that lessons of immense value to us might be gleaned from history as an aid in stimulating the spirit of research. What have the ancients to offer us? If achievement comes by means of spiritual forces then the animus of research must be spiritualized. Too much have we strayed from the simplicity of spirit which ruled the mind of the savant on the isle of Penikese who had

come in search of truth  
Trying with uncertain key  
Door by door of mystery.

Too much have we been stimulated by personal ambition in our "search for truth." Promotion, because of the amount of research we do is not the spiritualization sought for in this plea. The fundamental virtue of the investigator is a passion for truth whatever it be and through whatever channels it may come. As Bosworth says,

One's only safety consists in a fair treatment of facts. One fact fairly treated leads to another, and this to another. Facts treated as they ought to be treated lead always to a larger life.

This means not only a larger life for the investigator but more particularly for the great human family about him. Imbued with this spirit the seeker after truth goes in its search with the altruistic ambition of making the world a better place to live in, in every sense of the word "making it safe for democracy."

Not of the sunlight,  
Not of the moonlight,  
Not of the starlight!  
O young Mariner,  
Down to the haven  
Call your companions,  
Launch your vessel,  
And crowd your canvas,  
And, e'er it vanishes